Design and Beam Test Results for the sPHENIX Electromagnetic and Hadronic Calorimeter Prototypes

March 31, 2017

- First technical publication for sPHENIX
- Documents R&D for the calorimeter systems thus far
- Reports results for the first joint EMCal/ HCal test beam
- Link to paper: https://wiki.bnl.gov/sPHENIX/images/e/e4/T-1044_publication_SubmissionCandidate1.pdf
- Wiki: https://wiki.bnl.gov/sPHENIX/index.php/T-1044_publication

- We are requesting final approval for submission
- Plan to submit to IEEE Transactions on Nuclear Science and arXiv

Timeline

- April 2016: Test beam at Fermilab [link]
- September 26, 2016: Release to calorimeter groups for comments [link]
- November, 2016: Structural review by calorimeter experts [link]
- January 11, 2017: First collaboration release [link]
- March 7, 2017: Second collaboration release [link]
- March 27, 2017: Final approval release to collaboration [link]

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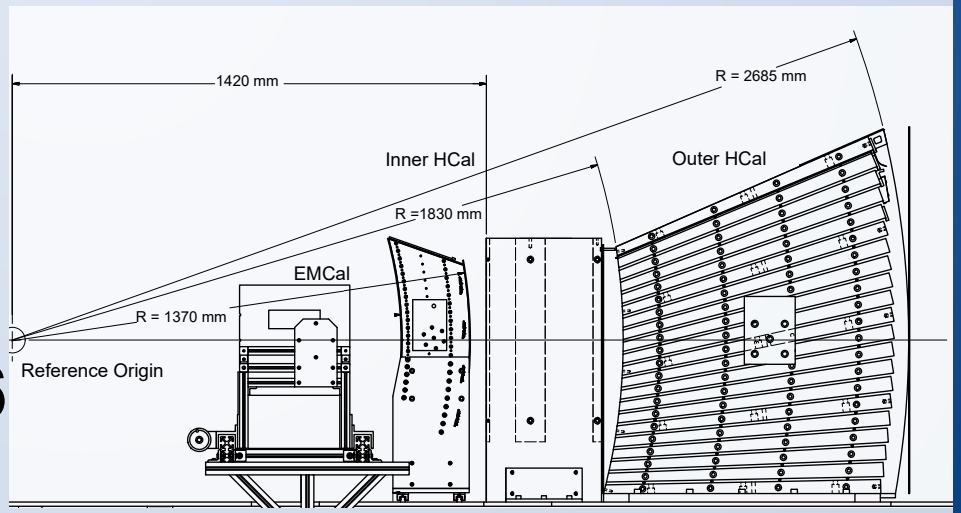
C.A. Aidala, V. Bailey, S. Beckman, R. Belmont, C. Biggs, J. Blackburn, S. Boose, M. Chiu, M. Connors, A. Franz, J.S. Haggerty, X. He, M.M. Higdon, J. Huang, K. Kauder, E. Kistenev, J. LaBounty, J.G. Lajoie, M. Lenz, W. Lenz, S. Li, V.R. Loggins, E.J. Mannel, T. Majoros, M.P. McCumber, J.L. Nagle, M. Phipps, C. Pinkenburg, S. Polizzo, C. Pontieri, M.L. Purschke, J. Putschke, M. Sarsour, T. Rinn, R. Ruggiero, A. Sen, A.M. Sickles, M.J. Skoby, J. Smiga, P. Sobel, P. Stankus, S. Stoll, A. Sukhanov, E. Thorsland, F. Toldo, R.S. Towell, B. Ujvari, S. Vazquez-Carson, C.L. Woody

***Abstract*—The sPHENIX experiment at the Relativistic Heavy Ion Collider (RHIC) will perform high precision measurements of jets and heavy flavor observables for a wide selection of nuclear collision systems, elucidating the microscopic nature of strongly interacting matter ranging from nucleons to the strongly coupled quark-gluon plasma. A prototype of the sPHENIX calorimeter system was tested at the Fermilab Test Beam Facility as experiment T-1044 in the spring of 2016. The electromagnetic calorimeter (EMCal) prototype is composed of scintillating fibers embedded in a mixture of tungsten powder and epoxy. The hadronic calorimeter (HCal) prototype is composed of tilted steel plates alternating with plastic scintillator. Results of the test beam reveal the energy resolution for electrons in the EMCal is $2.8\% \oplus 15.5\%/\sqrt{E}$ and the energy resolution for hadrons in the combined EMCal plus HCal system is $13.5\% \oplus 64.9\%/\sqrt{E}$. These results demonstrate that the performance of the proposed calorimeter system is consistent with GEANT4 simulations and satisfies the sPHENIX specifications.**

The author list is a self-identified (via the survey that was sent to the sPHENIX list) group of collaborators who contributed to the project.

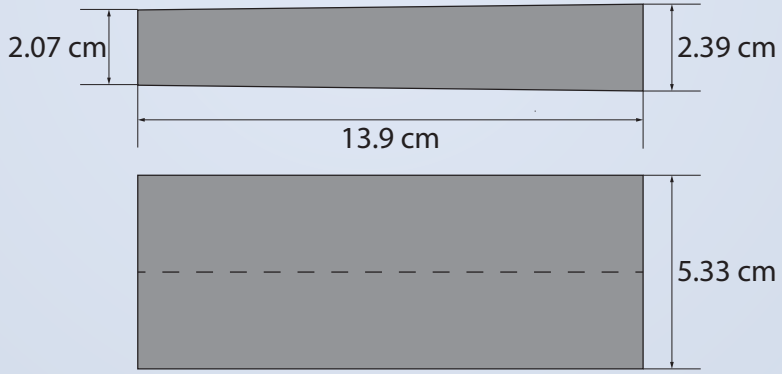
Introduction

- Introduction to sPHENIX
- Requirements for calorimetry:
  - EMCal: compact, fine segmentation, resolution must be 15%/√E or better
  - HCal: resolution 100%/√E or better for full calorimeter system
- Prototype EMCal and HCal tested at Fermilab Test Beam Facility in Spring 2016



Prototype EMCal

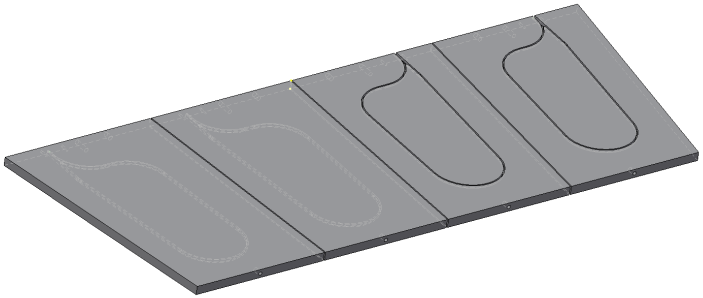
- Produced at UIUC and THP
- Blocks made of tungsten embedded with scintillating fibers
- Acrylic light guides on ends attach to SiPMs
- Blocks are 1D projective

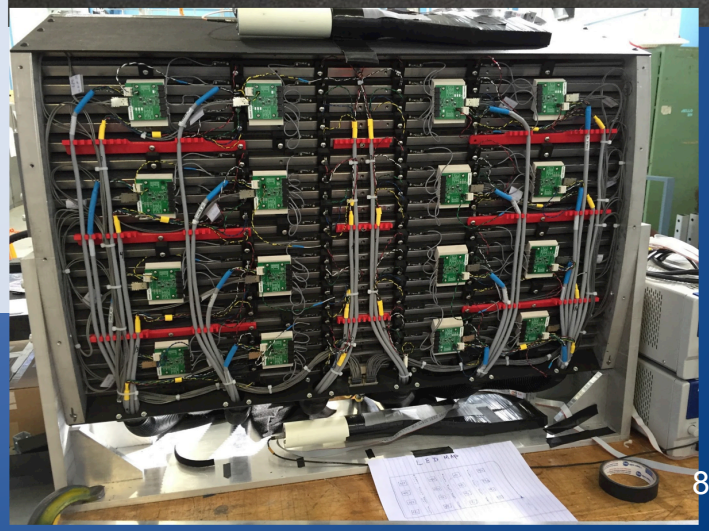


- Each of the 32 blocks in prototype are 2 towers for a total of 64 towers

Prototype HCal

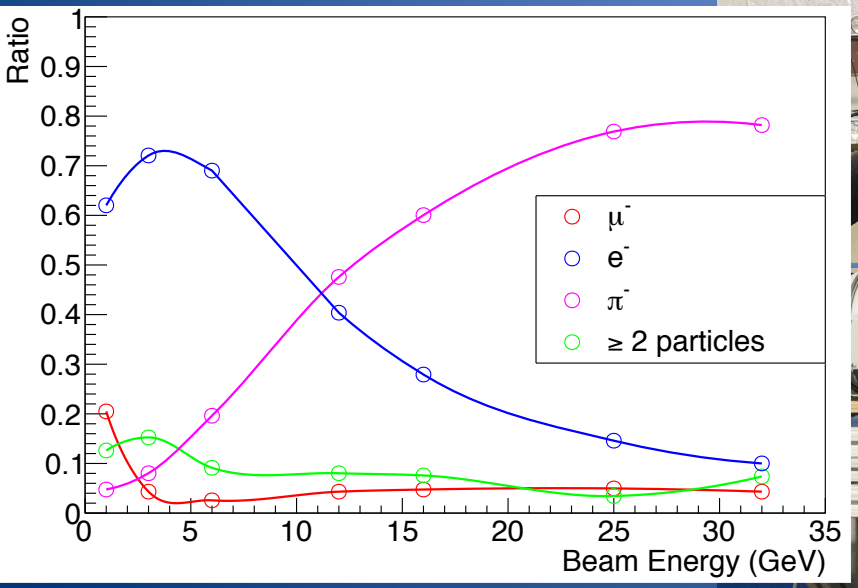
- Produced at UNIPLAST
- Consists of Inner (inside magnet) and Outer HCal sections
- Alternating layers of scintillator tiles and steel absorber plates
- Scintillator tiles made from extruded plastic with embedded wavelength shifting fibers
- Read out by SiPM

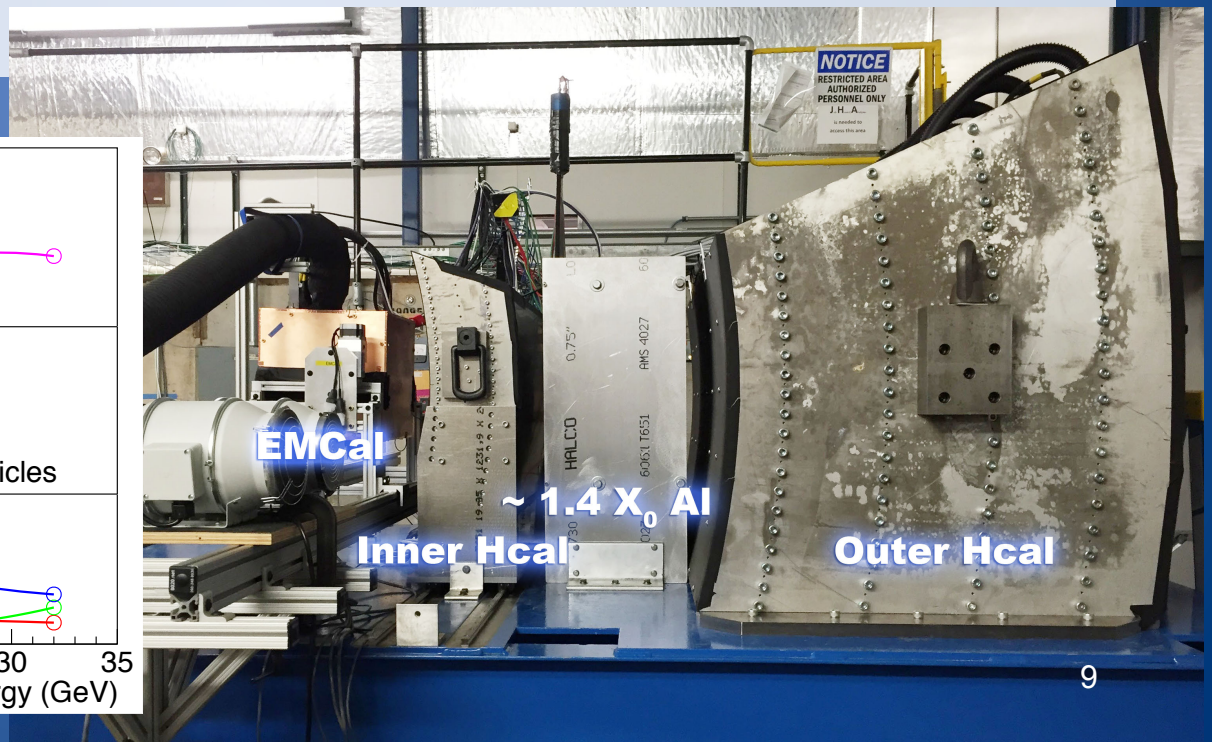




Test Beam

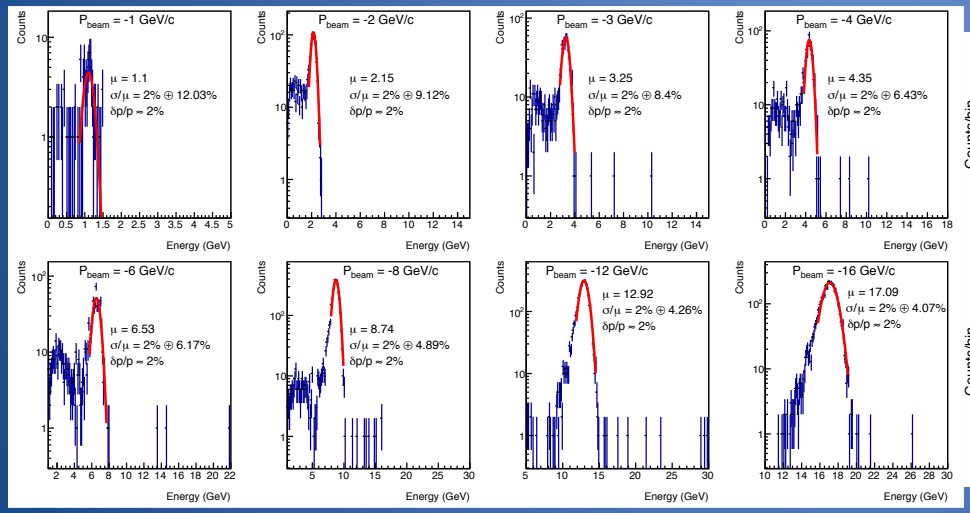
- Experiment T-1044 at FTBF
- Beam of primary protons at 120 GeV and a secondary mixed beam
- Calorimeters were tested individually and in combination

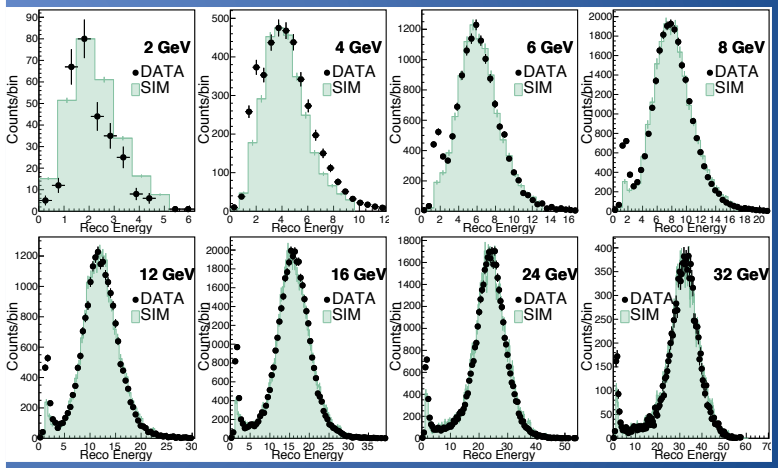




Calibration and Response

- EMCal calibrated with MIP events from beam
- HCal calibrated with cosmic MIP events

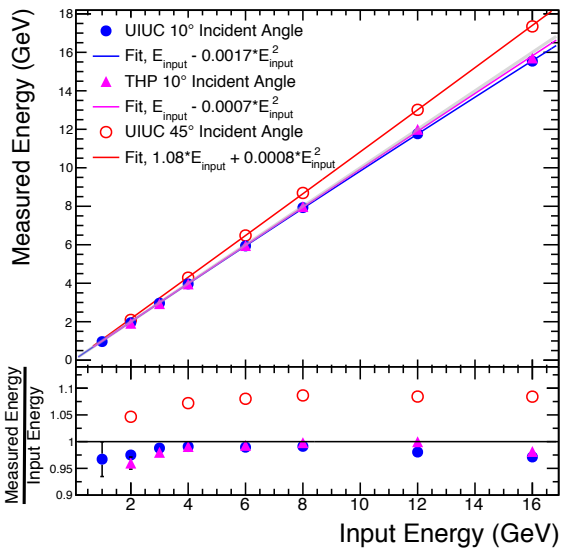


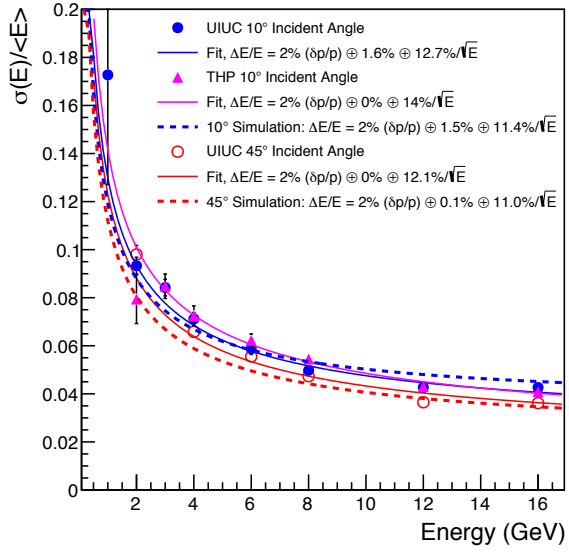


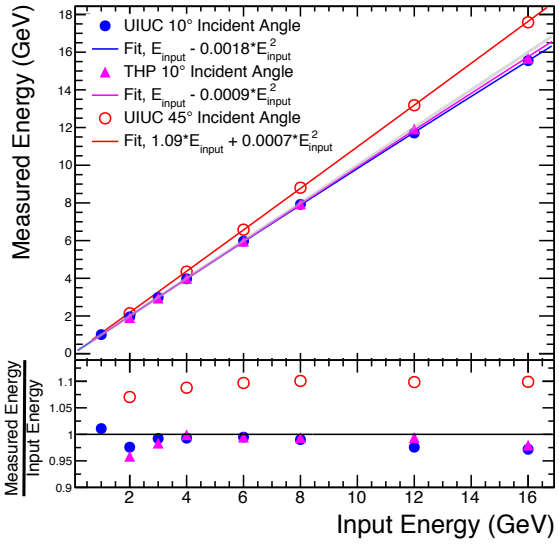
Electron response in EMCal

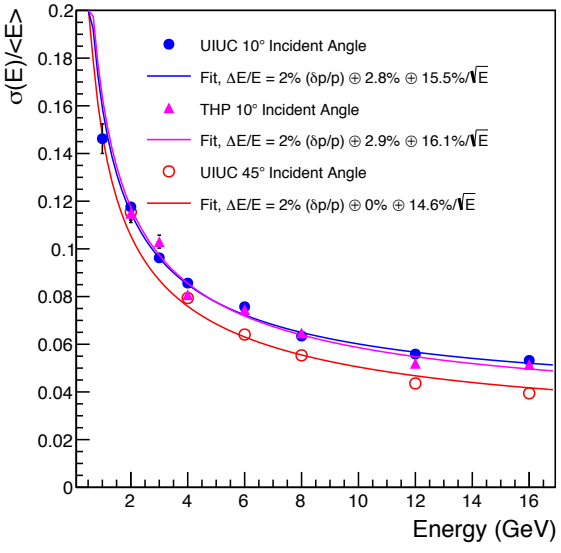
π- response in HCal

Results: EMCal







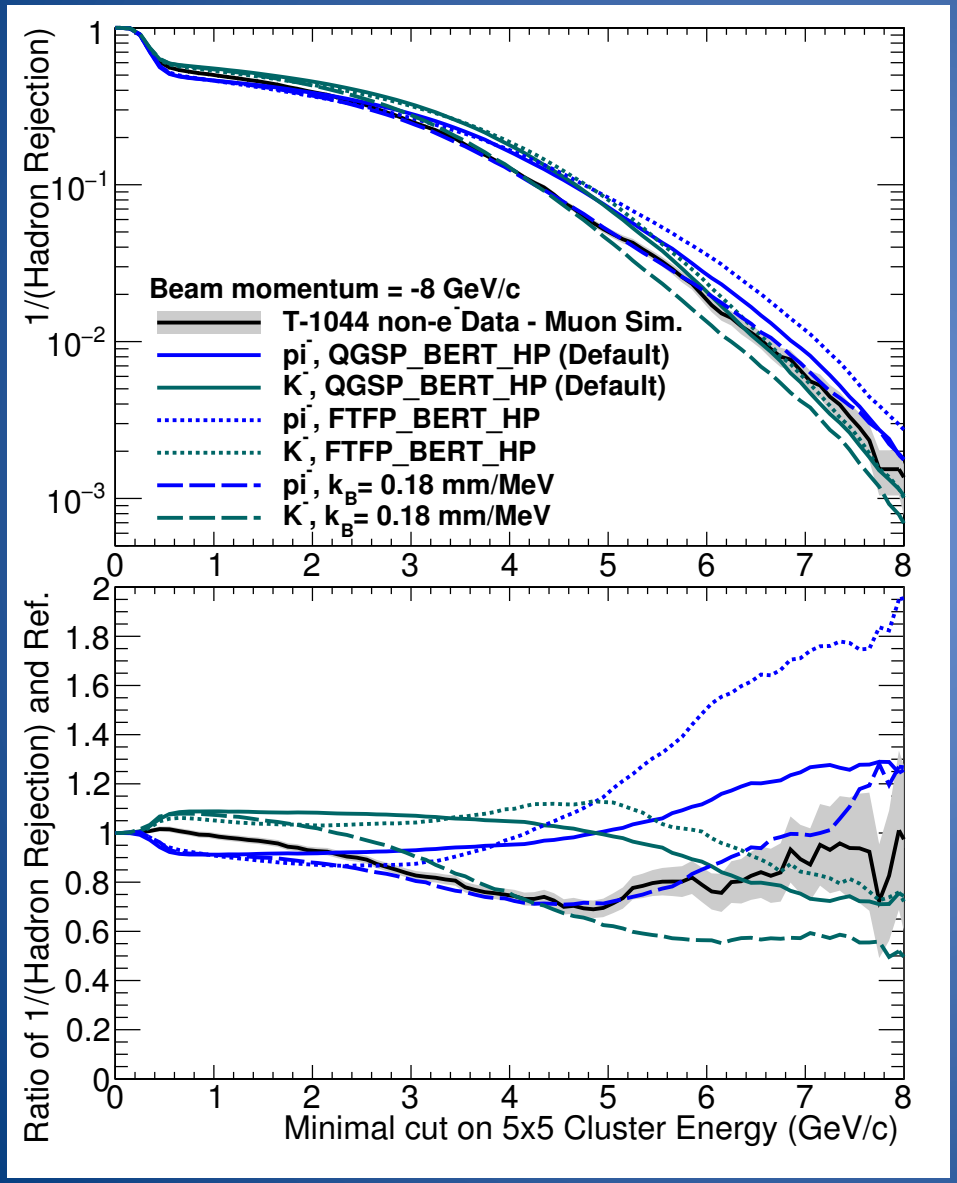


- Resolution and linearity measured for:

  (top) center of a tower, 12.7%/√E

  (bottom) across a tower, 15.5%/√E

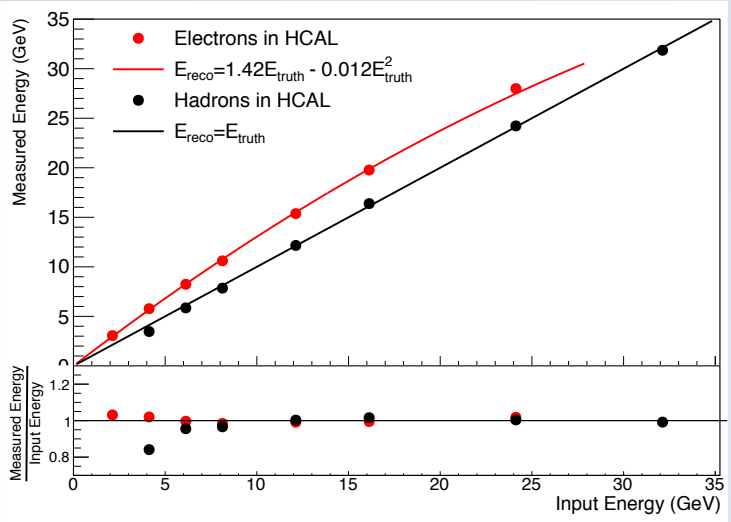
Results: EMCal

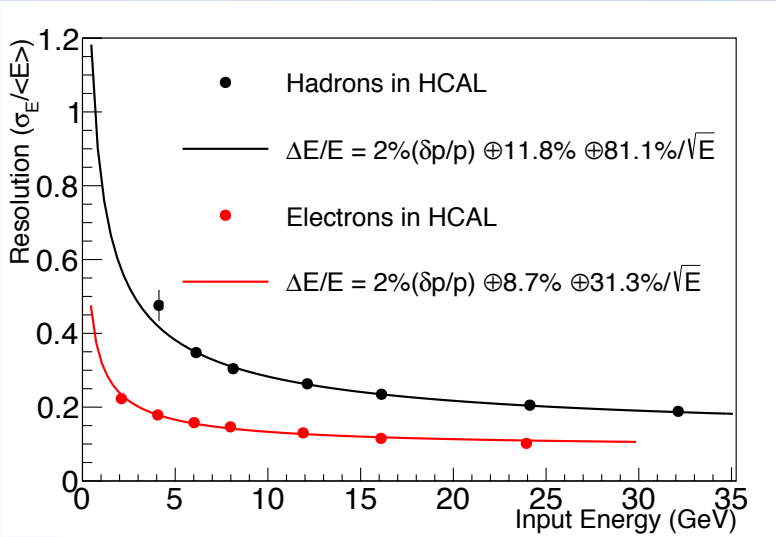


- Hadron events selected using Cherenkov detectors to measure hadron rejection in the EMCal

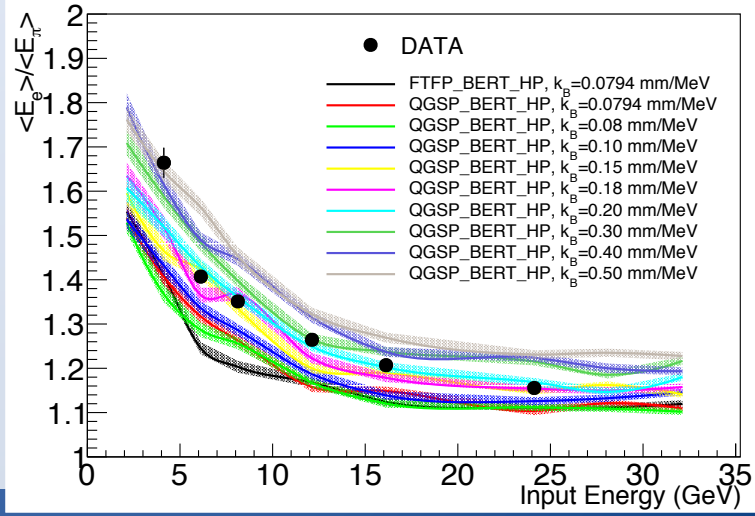
Results: HCal

- Resolution and linearity for electrons and hadrons



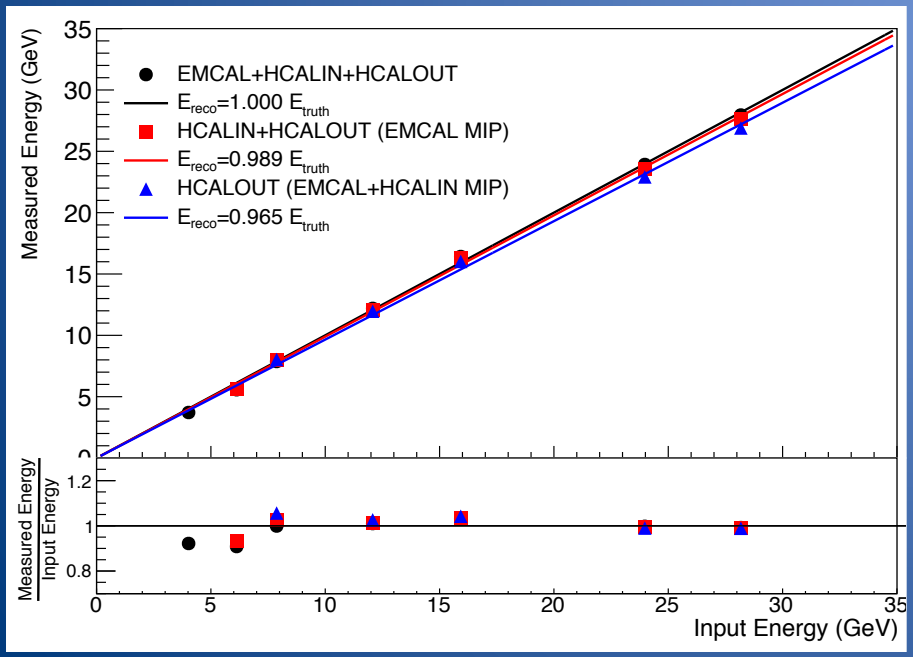


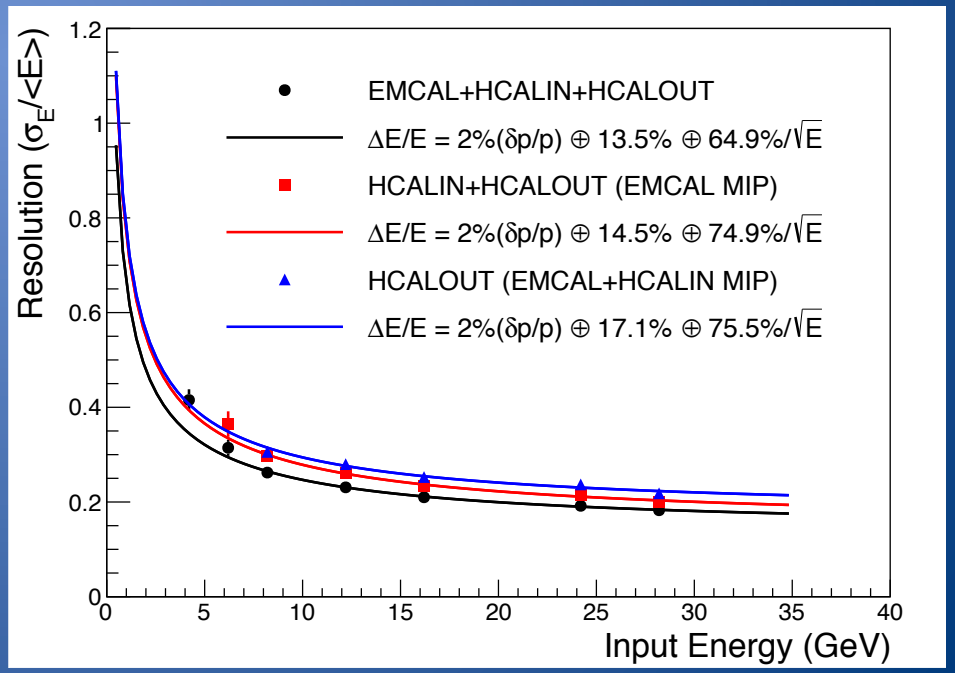
- HCal ⟨Ee⟩/⟨Eπ⟩ response



Results EMCal+HCal

- Hadron resolution and linearity in combined calorimeter system
- Satisfies sPHENIX hadron energy resolution requirements





Conclusions

- Energy resolution for:
  - Electrons that hit the center of the EMCal is $1.6\% \oplus 12.7\%/\sqrt{E}$
  - Electrons without position restriction in EMCal is $2.8\% \oplus 15.5\%/\sqrt{E}$
  - Hadrons in the HCal alone is $11.8\% \oplus 81.1\%/\sqrt{E}$
  - Hadrons in the full calorimeter system is $13.5\% \oplus 64.9\%/\sqrt{E}$
- Agree well with simulation
- Satisfy the sPHENIX requirements

- Thank you to all who contributed to the paper and have provided comments on drafts!